Consideration of Design Guidelines for Flow-through BMPs and use of Unit Hydrographs

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Transportation & Environmental Services Department

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Introduction

The City of Alexandria, Virginia has contracted with CH2M HILL to complete a Storm Sewer Capacity Analysis for each of their separate storm sewer sheds. As an initial effort in the project, CH2M HILL reviewed and proposed revisions to the City's stormwater design criteria through a series of four subtasks:

- Subtask 1.1—Benchmark the City's Stormwater Design Criteria with Neighboring Jurisdictions
- Subtask 1.2—Update Precipitation Frequency Results and Synthesize New IDF Curves
- Subtask 1.3—Rainfall Frequency and Global Climate Change Model Options for Study Area
- Subtask 1.4—Sea Level Rise Potential for the City of Alexandria, Virginia

An additional task (subtask 1.5) was requested by the City, considering development of a unit hydrograph specific to the City of Alexandria and considering possible design criteria to be set forth by the City for flow-through type BMPs to facilitate updates to the City's drainage criteria. This technical memorandum documents the information gathered on these topics and resulting recommendations.

Approach

During Task 1.5 CH2M HILL discussed the current design guidelines with the City, how unit hydrographs are used under the current design guidelines, and the need for new design guidelines. CH2M HILL staff consulted a range of design engineers and reviewed a range of design criteria from other jurisdictions, including Fairfax County, Virginia, who currently have a unit hydrograph defined in their Public Facilities Manual (PFM).

Unit Hydrographs

A unit hydrograph is the direct runoff hydrograph resulting from 1 inch of excess rainfall generated uniformly over a drainage area at a constant rate for an effective duration (Hinks and Mays, 1996). It can be used to derive the hydrograph for any amount of excess rainfall, assuming constant and uniform rainfall. The City of Alexandria does not currently have a unit hydrograph (UH) defined. In the past, City staff have pointed designers and developers to the Fairfax County PFM unit hydrograph as a resource for design. City staff requested that CH2M HILL consider the need for creating a unit hydrograph specific to the City.

There are several approaches available for developing a runoff hydrograph during design; however, one of the most common is the Soil Conservation Service (now Natural Resources Conservation Service, NRCS) method described in the SCS National Engineering Handbook - Section 4 (NEH-4). This approach uses a unit hydrograph, with a shape defined by a shape factor or peak rate factor. The typical shape factor is 484 for a hydrograph where the volume under the falling side of the triangular unit hydrograph is equal to 1.67 times the volume under the rising limb of the curvilinear unit hydrograph. Recommended shape factors may vary from 100 in very flat swampy areas to 800 in steep rocky terrain; however, SCS recommends the use of 484 for most watersheds.

A site specific unit hydrograph could be considered and developed; however, measured flow and rainfall data should be considered for a range of events and locations in order to develop a unit hydrograph that is representative of the City as a whole. Available flow data upon which to base this analysis are limited to one location: in Cameron Run downstream of the confluence with Backlick Run. CH2M HILL does not believe that data from one location would be sufficient to build a defensible unit hydrograph for the City as a whole. In addition, a UH developed at this scale would not necessarily be applicable to development projects which cover much smaller areas that are typically highly impervious with short time of concentrations.

According to Fairfax County staff, the unit hydrograph provided in the Fairfax PFM (http://www.fairfaxcounty.gov/dpwes/publications/pfm/) was not developed as a County-specific unit hydrograph. Instead, it was an application of the SCS unit hydrograph with the standard shape factor of 484 and Type II rainfall distribution and was provided to simplify design. It was typically used in Fairfax County for design of infiltration trenches in the past, but is rarely used today. The Virginia BMP Clearinghouse Specification Number 8, Infiltration Practices, is the current sizing calculation guidance document for infiltration devices by the County (Meyers, 2014).

Given the limited amount of data available, the fact that the characteristics of the City watersheds (slope and depression storage) are not particularly atypical, and the standard use of the SCS hydrograph in the industry, the development of an Alexandria-specific unit hydrograph is not recommended at this time. Therefore, CH2M HILL recommends that the City clarify in its drainage criteria that the NRCS unit hydrograph method should be used with a shape factor of 484 unless an applicant can demonstrate that a different method (or shape factor) is justified for a particular development.

Flow-Through BMP Design Guidelines

Over the past several years regulators have generally focused on treatment volume to set design standards for water quality BMPs. As a result, design requirements for flow-through BMPs, such as oil/particle separators, filters, and hydrodynamic separators, which provide water quality treatment but are designed based on a design flow rate and not a total treatment volume, have not been clear. The City of Alexandria requested CH2M HILL provide a recommendation on requirements that could be set for flow-through devices. The peak flow rate associated with the water quality volume is not only important in design of flow-based treatment devices, but also in design and sizing of treatment system components, such as pretreatment cells, level spreaders, by-pass diversion structures, and overflow riser structures. This section describes a variety of methods reviewed that other municipalities and flow-through BMP vendors are using.

Descriptions of Common Methods

Modified NRCS Curve Number (CN) Method Adopted in Virginia Stormwater Management Handbook, based on Claytor and Schueler (1996) Method

Although not specified as a flow-through design requirement, Virginia has promoted the NRCS TR-55 Graphical Peak Discharge Method with a modified curve number (Claytor and Schueler, 1996) as an approach to computing a peak flow rate associated with the water quality ("treatment") volume. This approach is documented in Section 11.5.3 of the Virginia Stormwater Management Handbook, Second Edition, draft July 2013, provided in Attachment 1. The draft Virginia Stormwater Management Handbook Second Edition text can be found at:
http://www.deq.virginia.gov/fileshare/wps/2013_SWM_Handbook/Chap_11/

Section 11.5.3 states that "…pretreatment cells, level spreaders, by-pass diversion structures, overflow riser structures, grass swales, and water quality swale geometry, etc. all require a peak flow rate of discharge in order to ensure non-erosive conditions and flow capacity." When runoff volume reducing green infrastructure practices are used, the 2013 calculation methodology includes a factor that will result in a lower treatment volume peak flow rate. This modified CN calculation method is still considered conservative when the drainage area is mostly pervious and runoff volume reducing BMPs are implemented. A more detailed storage routing calculation of the storage volume of the BMP (e.g., void space within a sand or stone layer) can be expected to result in a lower peak discharge rate than the calculated method of Section 11.5.3.

Several other jurisdictions, including New Hampshire, Connecticut, New York, Massachusetts, and West Virginia, have adopted this modified curve number approach for development of a water quality flow. In Massachusetts a study compared the Claytor and Schueler approach to several other approaches and found that the Claytor and Schueler method was the most complete in attempting to transform the Water Quality Volume to a flow rate (Massachusetts Department of Environmental Protection Wetlands Program, 2013).

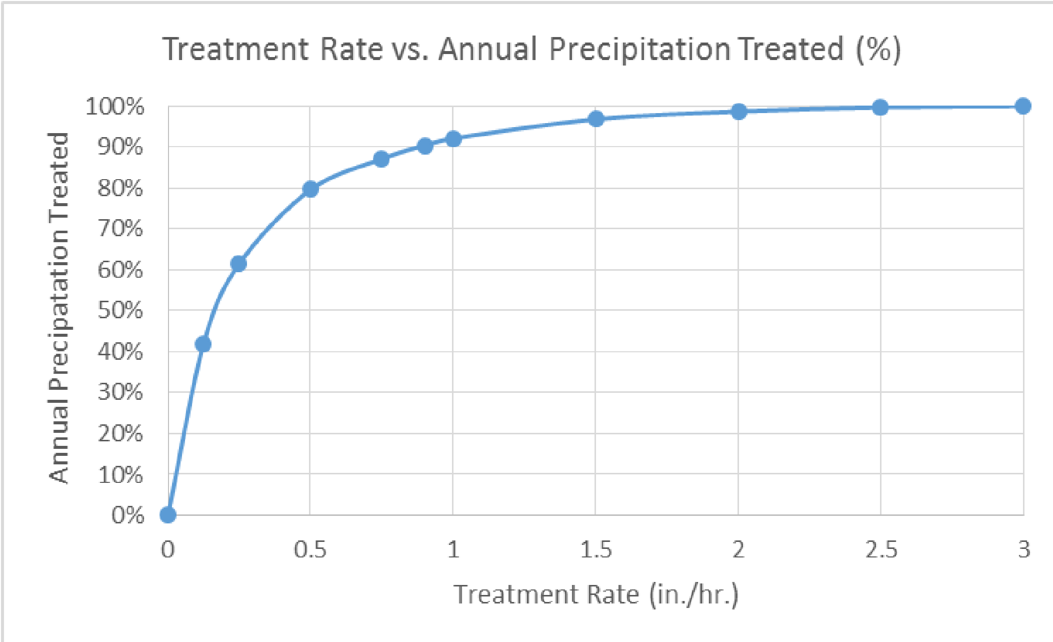
Stormwater Quality Design Storm in NJ

In New Jersey a rainfall distribution for a Stormwater Quality Design Storm has been defined, which is a 2-hour, 1.25-inch storm. The rainfall distribution can then be used for routing and to determine peak runoff rates for design purposes (New Jersey DEP, 2004).

Treatment Rate Curve Based on Long-Term Continuous Simulation

Another approach is to use a long-term simulation of rainfall/hydrology to create a treatment rate curve (see example in Figure 1). A threshold could then be set to treat a certain percent of all runoff (e.g., treat all flows up to the rate which captures 95% of long term or average annual rainfall). CH2M HILL used this approach for flow-rate based designs as part of the Save the Rain program in Onondaga County, NY. This approach is also used by the State of California.

FIGURE 1
Example treatment rate curve from Onondaga County, NY Save the Rain program



NRCS Type II 24 hour Storm Runoff Method

There was not a specific calculation method prescribed in the 1999 Virginia Stormwater Management Handbook First Edition for calculating a treatment volume peak flow rate; it only specified a treatment volume of 0.5 inches of runoff per impervious acre. Based on that, Contech Engineered Solutions, a leading supplier of manufactured BMPs, has used a treatment flow rate of 0.80 cfs per impervious acre in a number of Virginia jurisdictions, including Alexandria. This rate was derived from the peak rate of a 0.7 inch NRCS Type II 24 hour storm, producing the aforementioned 0.5 inches of runoff volume from an impervious surface. This approach is also by the Philadelphia Water Department for routing green infrastructure systems.

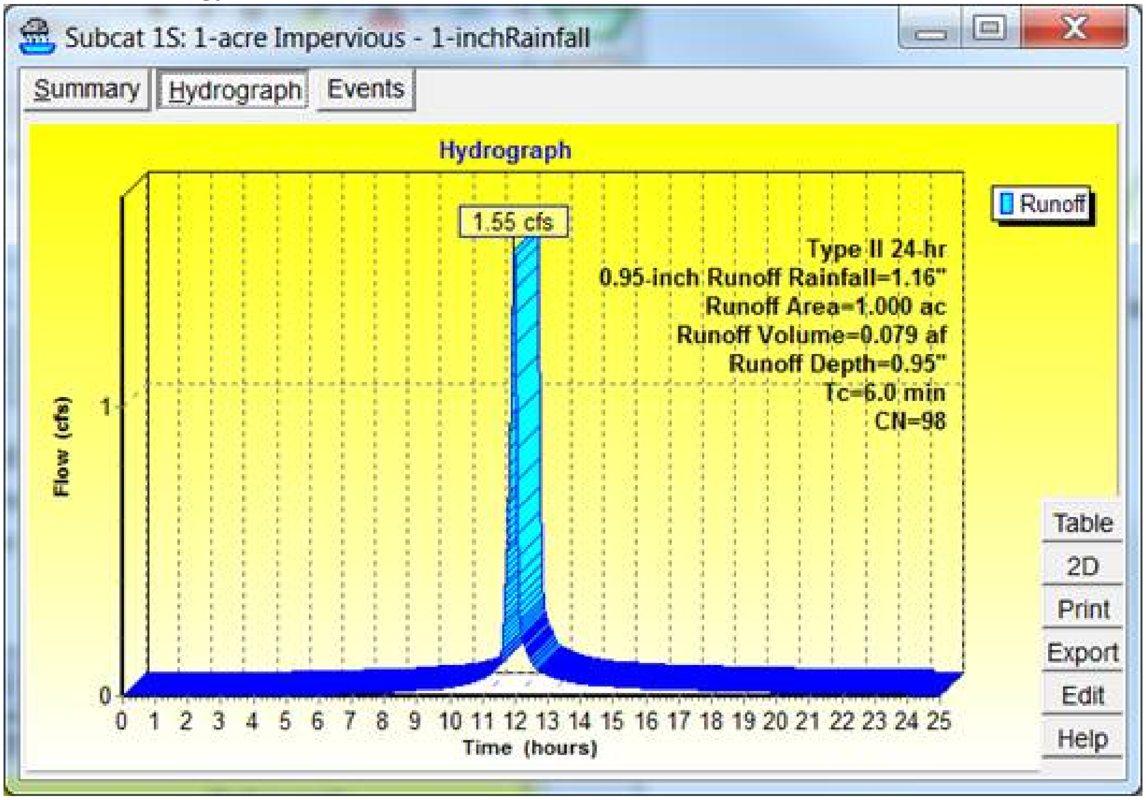
Comparison of Methods with an Example Case Study

For flow-through BMPs, such as manufactured devices, the drainage areas are typically small, highly impervious, and the impervious area is directly connected. The time of concentration is typically the NRCS method minimum of 0.1 hours (6 minutes) and the adjusted CN greater than 95. In the 2013 VA DEQ recommended method, the unit peak discharge rate from the NRCS Exhibit 4-II nomograph for these cases is 1000 cfs/mi^2/in; or 1.56 cfs/acre/in. See Attachment 2 for a highlighted copy of this nomograph. The unit peak discharge rate is then multiplied by the runoff in watershed inches as calculated from the adjusted CN. In the example included as Attachment 3, the 2013 DEQ calculation method adjusted the sample drainage area from a composite CN of 90 to an effective CN of 96, which roughly doubles the runoff volume (0.33 inches to 0.63 inches) and therefore doubles the resulting calculated treatment peak flow rate.

An example applying the NRCS type II 24-hour storm runoff methodology used by Contech Engineered Solutions is shown in Attachment 3. Note that applying this method for 0.95 inches of runoff (the new VA DEQ treatment volume requirement for impervious areas) by using a rainfall of 1.16 inches for impervious surfaces with a CN of 98 results in a rate of 1.55 cfs per impervious acre (see Figure 2), very close to the 1.56 cfs/acre from the 2013 DEQ method described above. Applying this to the 3.69 acres of impervious in the case study example yields a peak rate of 5.72 cfs.

FIGURE 2

Hydrograph associated with 0.95 inches of runoff from 1 impervious acre using the NRCS type II 24-hour storm runoff methodology



And finally, using the continuous simulation method that Onondaga County, NY performed, CH2M HILL ran an XPSWMM model to simulate a typical year of runoff for the example drainage area shown in Attachment 3. Fifteen minute interval rainfall data from Beltsville, MD was selected to simulate the typical rainfall year of 1984 (Beltsville was used instead of Reagan National Airport because it provided 15 minute rainfall data, which is much closer to the 6 minute time of concentration for the example, whereas only hourly data was available from the airport for the typical year of 1984). In contrast to typical design calculations based on more rare and extreme events, continuous simulation provides results across the range of rainfall events and an estimate of long-term performance.

TABLE 1

Comparison of Calculation Method Results using Drainage Area shown in Attachment 3

Method	Water Quality Treatment Flow Rate (cfs)	Comments
2013 DEQ 2nd Ed VSWM	5.84	Conservative. Based on current state Treatment Volume.
NRCS type II 24-hour storm runoff (applied to impervious area)	5.72	Easy to apply and incorporate into commonly used computer models. Based on 0.95 inches of runoff.
XPSWMM continuous simulation model, 1984 15-minute data	3.44	90% of annual runoff volume occurs at flow rates <3.44 cfs, 98% occurs at flow rates <5.84 cfs. 5-minute rainfall data would be expected to result in higher flows but is not available locally for the 1984 typical year

As shown in table 1, The 2013 DEQ recommended method produces a peak rate very similar to the NRCS type II 24-hour storm method and approximately 70% higher than the 90 percentile peak rate from continuous modeling with 15-minute rainfall. A conservative rate has benefits in meeting the statistical trend of greater frequency of high intensity events predicted by climate change models. A higher design flow rate also provides a factor of safety for the less than ideal performance that can occur from debris clogging, etc.

Recommendations

Unit Hydrographs

Given the limited amount of data available, the fact that the characteristics of the City watersheds (slope and depression storage) are not particularly atypical, and the standard use of the NRCS hydrograph in the industry, the development of an Alexandria-specific unit hydrograph is not recommended at this time. Therefore, CH2M HILL recommends that the City clarify in its drainage criteria that the NRCS unit hydrograph method should be used with a shape factor of 484 unless an applicant can demonstrate that a different method (or shape factor) is justified for a particular development.

Flow-Through BMP Design Guidelines

The Claytor and Schueler 1996 method appears to have become a commonly accepted approach for converting a water quality volume into a peak discharge. It formed the basis of the method recommended in the Virginia Stormwater Management Handbook, Second Edition, draft July 2013. The approach is logical and consistent with VA DEQ recommendations and is therefore recommended for use in the City of Alexandria. Using TR-55, an NRCS Type II 24 hour storm, and the 0.95 inches of runoff for impervious areas is an acceptable alternative for most sites which produces very similar results.

References

Hinks, R.W. and L.W. Mays, 1996. *Water Resources Handbook, Chapter 24: Hydrology for Water Excess Management,* McGraw-Hill.

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National Engineering Handbook Hydrology Chapters (originally published as (NEH-4). http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/?&cid=stelprdb1043063 (accessed on 12/9/14).

Massachusetts Department of Environmental Protection Wetlands Program. 2013. *Standard Method to Convert Required Water Quality Volume to a Discharge Rate for Sizing Flow Based Manufactured Proprietary Stormwater Treatment Practices.*

Claytor, R. and T. Schueler, 1996. *Design of Stormwater Filtering Systems.* Center for Watershed Protection. Ellicott City, MD.

New Jersey DEP, 2004. New Jersey Stormwater Best Management Practices Manual. Chapter 5: Computing Stormwater Runoff Rates and Volumes. February 2004.

Virginia DEQ, 2013. Virginia Stormwater Management Handbook, Second Edition. Chapter 11.5.3: Water Quality Design (Tv) Peak Flow Rate. July 2013.

Attachment 1
Section 11.5.3 of the Virginia Stormwater Management Handbook, Second Edition, draft July 2013
Water Quality Design Tv Peak Flow Rate

	Urban Planter	✓		✓
Bioretention		✓		✓
Permeable Pavement		✓		✓
Grass Swale		✓		✓
Infiltration		✓		✓
Rainwater Harvesting		✓		
Vegetated Roof		✓		✓
Filtration		✓		✓
Extended Detention		✓		✓
Stormwater Wetlands			✓	✓

[1] Minimum design criteria for storage volume.
[2] Minimum design for surface area of the practice.
[3] Minimum design criteria include storage volume and surface area design features.

11.5.3 Water Quality Design *Tv* Peak Flow Rate

The peak flow rates for the 1-year 24-hour storm and larger storms are readily computed using accepted hydrologic methods outlined in this chapter. However, there has not been a standard method for computing the water quality design peak flow rate. The water quality design peak flow rate is needed for the design and sizing of pretreatment cells, level spreaders, by-pass diversion structures, overflow riser structures, grass swales and water quality swale geometry, etc. All require a peak rate of discharge in order to ensure non-erosive conditions and flow capacity.

Of the hydrologic methods available, the Rational Formula is highly sensitive to the time of concentration and rainfall intensity, and therefore should only be used with reliable Intensity-Duration-Frequency (IDF) curves (or B, D, & E factors discussed in **Section 11.3.1** on page 11-9 above) for the rainfall depth and region of interest (Claytor and Schueler, 1996). Unfortunately, there are no IDF curves or B, D, & E factors available for the 1-inch rainfall depth. The NRCS *CN* methods are very useful for characterizing complex sub-watersheds and drainage areas and estimating the peak discharge from large storms (greater than 2 inches), but can significantly underestimate the discharge from small storm events (Claytor and Schueler, 1996). Since the *Tv* is based on a 1-inch rainfall, this underestimation of peak discharge can lead to undersized diversion and overflow structures, resulting in a significant volume of the design *Tv* potentially bypassing the runoff reduction practice. Undersized overflow structures and outlet channels can cause erosion of the BMP conveyance features which can lead to costly and frequent maintenance.

In order to maintain consistency and accuracy, the following Modified *CN* Method is recommended to calculate the peak discharge for the 1-inch rain event. The method uses the Small Storm Hydrology Method (Pitt, 1994) and NRCS Graphical Peak Discharge Method (USDA, 1986) to provide an adjusted Curve Number that is more reflective of the runoff volume from impervious areas within the drainage area. The design rainfall is a NRCS Type II distribution, so the method incorporates the peak rainfall intensities common in the eastern United States. The time of concentration is computed using the method outlined in TR-55.

The following provides a step by step procedure for calculating the Water Quality Treatment Volume's peak rate of discharge, $\boldsymbol{q_{pTv}}$:

Step 1: Calculate the adjusted *CN* for the site or contributing drainage area.
The following equation is derived from the NRCS *CN* Method and is described in detail in the Part 630 (Hydrology) of the NRCS National Engineering Handbook:

Equation 11.11 Derivation of NRCS Curve Number and Runoff Equation

$$CN = \frac{1000}{[10 + 5P + 10Q_a - 10(Q_a^2 + 1.25Q_aP)^{0.5}]}$$

Where:

CN = Adjusted curve number
P = Rainfall (inches), (1.0" in Virginia)
Q_a = Runoff volume (watershed inches), equal to $Tv \div drainage\ area$

Note: When using a hydraulic/hydrologic model for sizing a runoff reduction BMP or calculating the q_{pTv}, designers must use this modified *CN* for the drainage area to generate runoff equal to the *Tv* for the 1-inch rainfall event.

Step 2: Compute the Time of Concentration (*Tc*) for the site or drainage area.
Chapter 4 of the ***Blue Book*** and Chapter 3 of TR-55 (Time of Concentration and Travel Time) provide detailed procedures for computing the *Tc*. The designer should select the *Tc* flow path that is representative of the impervious cover. .

Step 3: Calculate the Water Quality Treatment Volume's peak discharge (q_{pTv})
The (q_{pTv}) is computed using the following equation and the procedures outlined in Chapter 4 (Graphical Peak Discharge Method) of TR-55.

Equation 11.12. Modified NRCS TR-55 Eq. 4-1

$$q_{pTv} = q_u \times A \times Q_a$$

Where:

q_{pTv} = Treatment Volume peak discharge (cfs)
q_u = unit peak discharge (cfs/mi^2/in)
A = drainage area (mi^2)
Q_a = runoff volume (watershed inches = *Tv/A*)

Designers can also use WinTR-55 or an equivalent TR-55 spreadsheet to compute (q_{pTv}):

- Read the initial abstraction (I_a) from TR-55 Table 4.1 or calculate it using $I_a = 200/CN - 2$

- Compute I_a/P ($P = 1.0$);
- Read the Unit Peak Discharge (q_u) from exhibit 4-II using Tc and I_a/P;
- Compute the (q_{pTv}) peak discharge:

This procedure is for computing the peak flow rate for the 1-inch rainfall event. All other calculations of peak discharge from larger storm events for the design of drainage systems, culverts, etc., should use published *CN*s and computational procedures.

11.5.4 On-Line and Off-Line BMPs

Runoff Reduction BMPs are typically sized and designed to manage the design treatment volume from the 1-inch rainfall event. In some cases designers may choose to manage or detain a larger storm event in order to partially or fully meet the quantity control requirements. In all cases, the designer must account for the conveyance of these larger storms *through* the BMP (the BMP is said to be ***On-Line***) or *around* the BMP (making the BMP ***Off-Line***).

Using the water quality design *Tv* peak flow rate described in **Section 11.5.3** above, the designer can size a bypass control for an *On-Line* BMP, such that flows that exceed the design capacity exit via an internal riser structure or weir overflow. This means that the BMP accepts all the runoff from the contributing drainage area and the overflow is within the BMP (or main treatment area). On-line BMPs must be carefully designed to accommodate the large storm design peak flow rate in terms of inflow velocity and energy, as well as an adequately sized overflow to allow the runoff to safely exit the BMP.

On-line systems in these cases will require careful design and construction to ensure adequate conveyance of the large storm inflow.

On-line systems should include the following:

- Inflow points should be protected from erosive velocity;
- An overflow structure must be provided within the practice to pass storms greater than the design storm storage to a stabilized conveyance or storm sewer system;
- Discharge from the overflow structure should be controlled so that velocities are non-erosive at the outlet point;

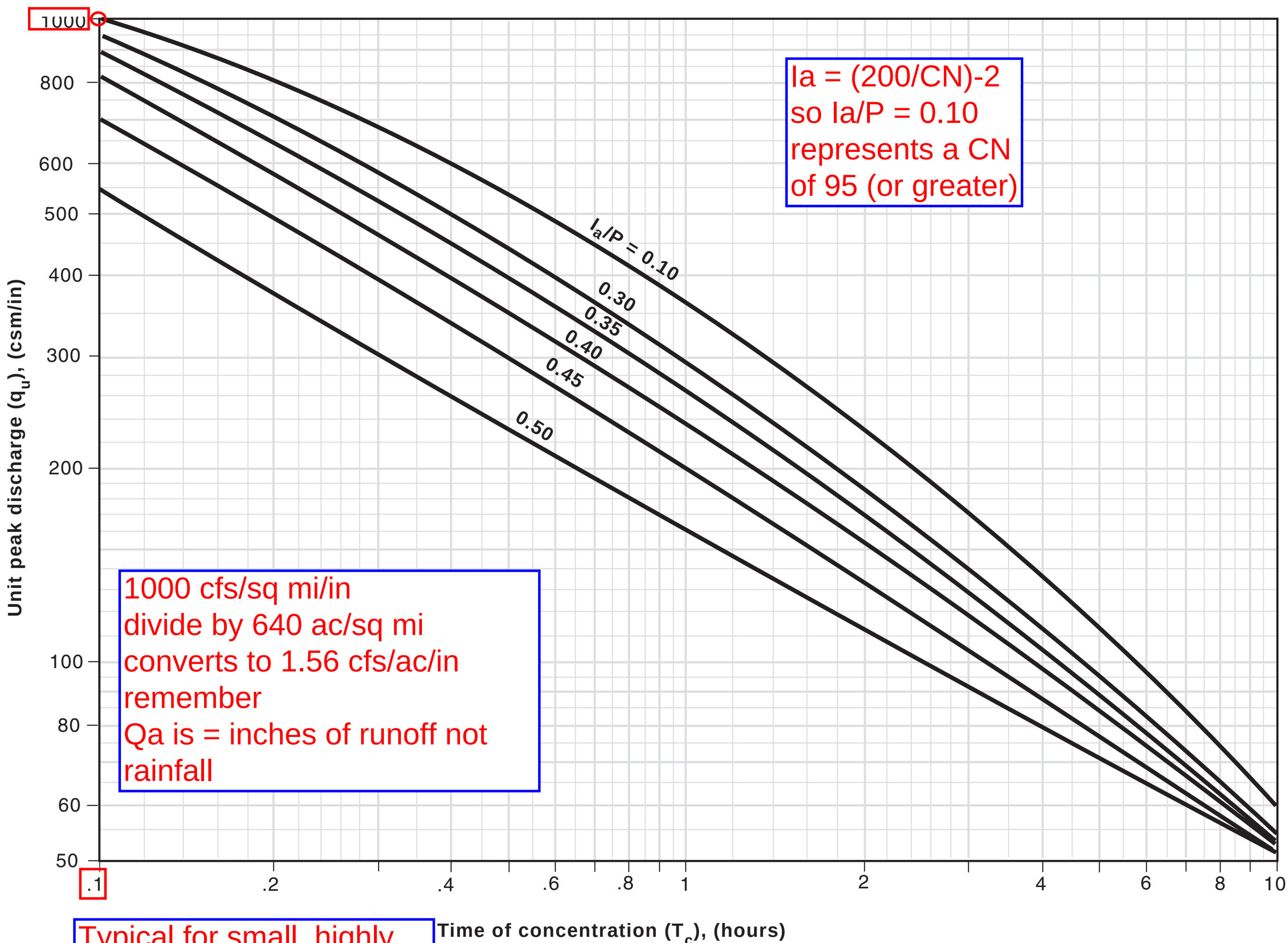
The overflow structure type and design should be scaled to the application – this may be a landscape grate or yard inlet for small practices or a commercial-type structure for larger installations.

Alternately, an *Off-Line* BMP design uses an external diversion structure to manage the large storm flow so the runoff in excess of the 1-inch rain event will not damage the BMP (excessive velocity or ponding depth) or re-suspend and export previously trapped pollutants. This can be accomplished through a low-flow diversion structure that channels the smaller storm flow volume into the BMP, while forcing the larger flows to bypass the BMP. These types of low-flow diversions or large storm bypass structures are external – thereby diverting the flow before it gets to the BMP – or they can be part of the BMP inlet structure, such as a forebay or level spreader. In some cases, off-line BMPs with a storage volume can be located so that once the

Attachment 2
SCS TR-55 Exhibit 4-II
Nomograph for unit peak discharge (qu) for NRCS (SCS) type II rainfall distribution

For use in equation
qvTv = qu * A * Qa

Exhibit 4-II Unit peal discharge (q_u) for NRCS (SCS) type II rainfall distribution



Typical for small, highly
impervious drainage area
DEQ Section 11.5.3
states that the Tc should
represent the directly
connected impervious
portion of the drainage
area

example:
1 acre, CN 98, Tc 0.1 hr, Qa =
0.816 inches runoff
qvTv = qu * A * Qa
qvTv = 1.28 cfs

Attachment 3
Case Study – Comparison of VDEQ 2013 Method with Continuous Simulation Method

DEQ 2013 CALCULATION METHOD:

FIRST: CALCULATE DRAINAGE AREA TREATMENT VOLUME WITH VRRM SPREADSHEET

Virginia Runoff Reduction Method New Development Worksheet - v2.8 - June 2014

Update Summary Sheet

Print

Site Data Summary

Total Rainfall = 43 inches

Site Land Cover Summary

	A Soils	B Soils	C Soils	D Soils	Total	% of Total
Forest (acres)	0.00	0.00	0.00	**1.69**	**1.69**	*28.26*
Turf (acres)	0.00	0.00	0.00	**0.60**	**0.60**	*10.03*
Impervious (acres)	0.00	0.00	0.00	**3.69**	**3.69**	*61.71*
					5.98	*100.00*

Site Rv	0.63
Post Development Treatment Volume (ft3)	13576
Post Development TP Load (lb/yr)	8.53
Post Development TN Load (lb/yr)	61.02
Total TP Load Reduction Required (lb/yr)	6.08

DEQ 2013 CALCULATION METHOD:

SECOND: CALCULATE PER EQUATIONS IN SECTION 11.5.3 OF 2013 VIRGINIA STORMWATER MANAGMENT HANDBOOK, SECOND EDITION

CH2MHILL

Water Quality Treatment
Volume (Tv)
Peak Flow Rate
per VSMH 2nd Ed. Section 11.5.3

Objective: Determine Water Quality Treatment Volume Peak Flow Rate

Notes:
1. Directly connected impervious area will dominate the runoff response for small storms
2. Time of concentration should represent the directly connected impervious area
3. This calculation is based on an adjusted Curve Number (CN).

Step 1. Equation 11.11 from draft VSMH 2nd Ed.
CN = 1000/(10+5P+10Qa -10((Qa)^2) + 1.25QaP)^0.5)
where Qa = Tv / drainage area, converted from feet to inches

Enter:
A. Tv to the point of interest. Calculated by VRRM spreadshe 13,576 (cf)

B. Drainage Area to point of interest (acres) 5.98

C. P = Precipitation (1.0 for WQ Tv) 1.0 (in)

D. for comparison only, weighted CN from VRRM channel protection tab 90

Results: Qa = (Tv/DA) *12 = 0.63 Watershed Inches

Adjusted CN = 96

Step 2. Compute the site or drainage area Time of Concentration (Tc)
For small urban drainage areas, use NRCS method minimum Tc of 6 minutes (0.1) hours
See note 2 above

Step 3. Equation 11.12 from draft VSMH 2nd Ed.

qpTv = qu * A * Qa where:

qpTv = Treatment Volume peak discharge (cfs)
qu = unit peak discharge (cfs/mi^2/in) [look up from TR-55 exhibit 4-II
based on Tc & Ia/P
qu = 1000 for Tc of 0.1 hr & Ia/P of 0.1,
typical for small urban DA treated by flow-through BMP
A = drainage area in sq.mi. (confirm correct unit conversion)
Qa = Tv/DA: calculated in results to Step 1

Calculated Ia/P = ((200/CN)-2)/I 0.08

qu from exhibit 4-II = 1000 cfs/mi^2/in

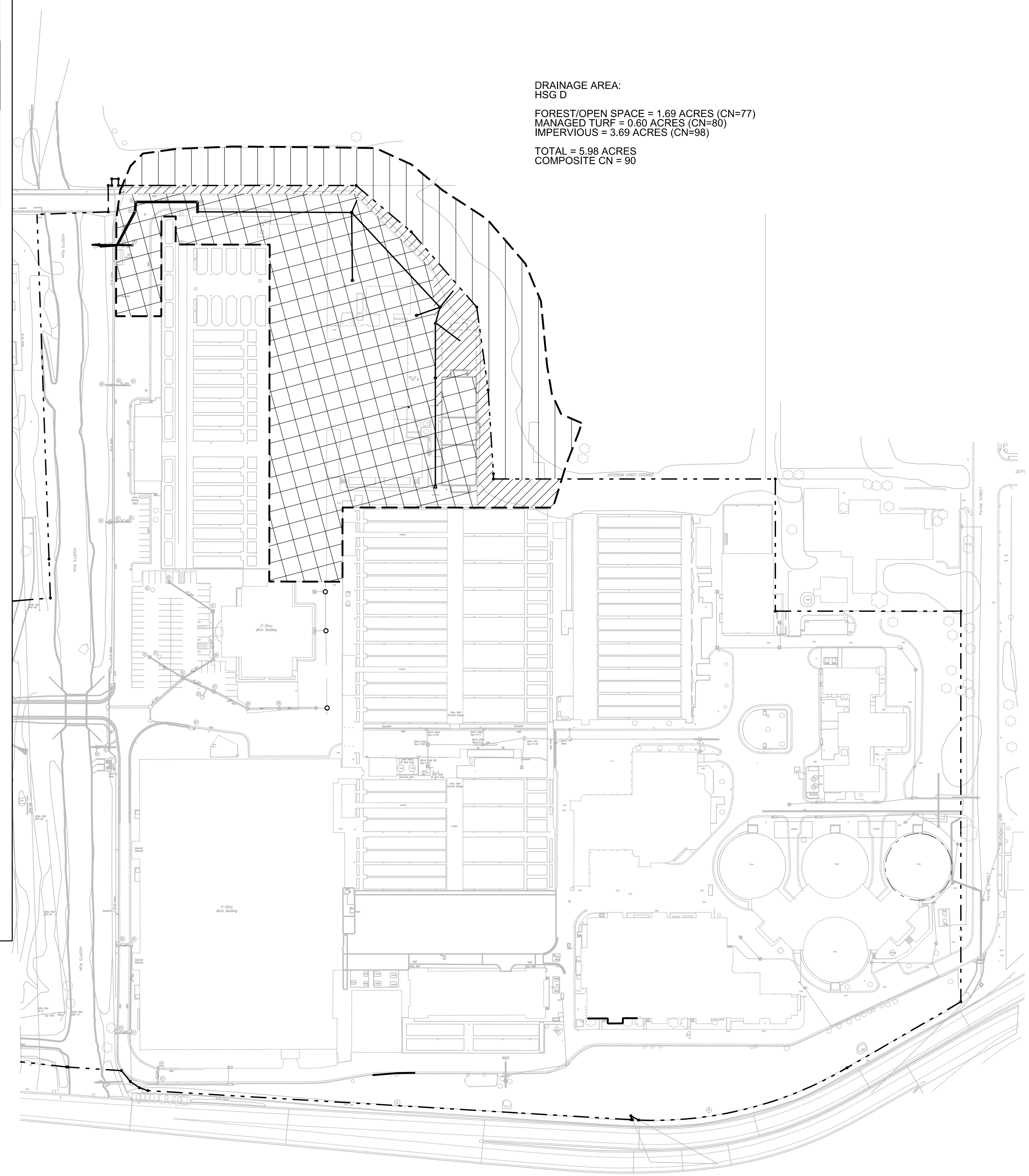
Results: qpTv = 5.84 cfs

COMPARISON TO 1999 METHOD:

WATER QUALITY PEAK FLOW RATE
DETERMINED TO BE PEAK FLOW RATE OF 0.5 INCHES OF RUNOFF VOLUME FROM 0.7 INCH STORM = 0.8 CFS PER IMPERVIOUS ACRE

IMPERVIOUS = 3.69 ACRES

Qtv = 0.8 CFS/AC * 3.69 AC
= 2.95 CFS



DRAINAGE AREA:
HSG D

FOREST/OPEN SPACE = 1.69 ACRES (CN=77)
MANAGED TURF = 0.60 ACRES (CN=80)
IMPERVIOUS = 3.69 ACRES (CN=98)

TOTAL = 5.98 ACRES
COMPOSITE CN = 90

N

0 100 200 300

LEGEND:

- STORM DRAIN
- DRAINAGE AREA
- FOREST/OPEN SPACE
- MANAGED TURF
- IMPERVIOUS

FIGURE 1

CASSCA TASK 1.5
TREATMENT VOLUME
PEAK FLOW RATE
CALCULATION EXAMPLE
2/16/15

CH2MHILL

$(MS_PLTDGNFILE_LONG)